

ROYAL TERN (*Sterna maxima*) CHICK DIET ON
FISHERMAN ISLAND NATIONAL WILDLIFE REFUGE, VIRGINIA

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ABSTRACT

I investigated Royal Tern (*Sterna maxima*) chicks on an uninhabited barrier island, Fisherman Island National Wildlife Refuge, at the mouth of the Chesapeake Bay, Virginia, during 2003 and 2004 to determine the seasonal variation in diet and the fisheries-related correlations in the availability of quality prey. Systematic observations of adults returning with food indicated that at least 19 families of fish, crustaceans, and squid were exploited. The most common forage species in both years were anchovies (Engraulidae) and herring (Clupeidae). Significant seasonal and annual variation occurred in prey type and size of prey, and a shift in prey occurred during the middle and later portions of the study during both years. However, time of day did not affect the proportion of anchovy and herring being fed to the chicks. These results suggest that prey abundance is the limiting factor in the diet of Royal Tern chicks.

ACKNOWLEDGMENTS

I have crossed trails with many different people over the years and they all have contributed to the current shape of my life. I know that I would not have arrived here without their support.

I would like to express my gratitude to my advisor, Steve Emslie, who gave me the opportunity to pursue my Master's degree. He took a chance on me that others were afraid to. Thank you.

Special thanks to my committee members, Dr. Bolen, Dr. Scharf, and Dr. Webster, with the conduct of my research and for their guidance and understanding during the revision phase. I would like to extend my heartfelt gratitude to Dr. Webster for his unyielding assistance and support- it will never be forgotten and always appreciated. Also, a sincere thank you to Dr. Frierson in helping with the statistical analysis.

My field research on the Eastern Shore of Virginia National Wildlife Refuge for two summers would not have been the enjoyable without the assistance and company of Pam Denmon, Bart Paxton, Matt Ramah, and Alex Wilke. The meaning of "going out in the field" brought many a smile to our faces.

I recognize that this research would not have been possible without the financial assistance of North Carolina Sea Grant, the University of North Carolina at Wilmington Graduate School, and the Carolina Bird Club. I express my gratitude toward these agencies.

Finally, I would like to thank the colony of Royal Terns on Fisherman Island for allowing me to be a part of their lives for two summers. Their patience and cooperation with data collection was appreciated and in turn my work may benefit future generations.

DEDICATION

I would like to dedicate this thesis to my parents, Sumer and Barbara Aygen, who have provided me with nothing less than support, encouragement, and love through my entire life. They have given me the gift of education, and it will be everlasting.

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INTRODUCTION

Diet composition and the availability of quality prey are important factors in the health and survival of animals. A number of studies have used seabirds as monitors of the marine environment by quantifying their sensitivity to reductions in prey availability and abundance (Amey and Diamond 1997; Furness and Camphuysen 1997; Furness and Tasker 2000; Barrett 2002). This sensitivity to prey fluctuations affects the survival, longevity, and reproductive success of seabirds (Burness et al. 1994; Cairns 1992; Furness and Camphuysen 1997; Kitaysky et al. 2000; Monaghan et al. 1992).

Seabirds have served as biomonitors of the marine environment in various regions of the Atlantic and Pacific oceans (Burness et al. 1994; Amey and Diamond 1997; Kitaysky et al. 2000; Barrett 2002), and the relationship between food supply and the breeding success of seabirds has suggested that they are able to adjust their breeding biology to favor individual survival over reproduction during periods of adversity (Monaghan et al. 1989a; Monaghan et al. 1992; Van Heezik and Davis 1992; Barrett 2002). In addition, seabirds often experience massive breeding failures due to the depletion of fish stocks (Vader et al. 1990; Anker-Nilssen et al. 1996; Regehr and Montevecchi 1997; Barrett and Krasnov 1996; Anker-Nilssen and Broseth 1998).

Dietary composition of seabirds also has been used to monitor prey stocks (Montevecchi 1993). Past studies have shown a positive correlation between the diets of seabird chicks and fish recruitment (Hamer et al. 1991; Montevecchi 1993; Bearhop et al. 2001). Diet composition can be determined by collecting discarded prey at the colony (Atwood and Kelley 1984), direct observations of chick feedings (Cezilly and Wallace 1988; Burness et al. 1994), and by capture of adults with prey (Barrett 2002).

Seabird diets often vary temporally, and the annual variation and distribution in prey availability and abundance may limit the growth, weight gain, and survival of offspring (Ricklefs et al. 1984; Monaghan et al. 1989b; Klaasen et al. 1992; Uttley 1992; Kitaysky et al. 2000; Takahashi et al. 2001; Granadeiro et al. 2003). Recent studies have shown that seabird chicks could serve as potential indicators of fish stocks. Their diet and growth rates suggest a correlation between the proportion of prey in their diet to the availability of fish in the area (Greenstreet et al. 1999; Barrett 2002). Hence, these birds have become vulnerable to the quality, quantity, and type of prey found in their diets, thus indicating that diet composition can serve as a crude assessment of the availability of resources in the marine ecosystem.

The Royal Tern (*Sterna maxima*) is a conspicuous colonial-nesting waterbird that primarily breeds on barrier islands or dredge spoil banks. Their breeding range extends along the east coast of North America and South America, and on the west coast of Africa. It also breeds in the Gulf of Mexico, southern California, and northern South American coasts (Buckley and Buckley 2002). This range consists primarily of fragile coastal habitat that is under intense pressure from humans for recreation and development. Royal Terns are long-lived, have a delayed sexual maturity, nest in dense breeding colonies, and usually lay a one-egg clutch. They are consistent inshore feeders, primarily on schooling fish, which they capture by plunge diving.

Because Royal Terns are plunge divers with energy-expensive foraging routines, a shift in prey availability also could have a negative effect on populations on the east coast. Breeding pairs of Royal Terns practice extended parental care during the chick and post-fledgling period and devote much of their energy budgets to feeding their young. Ashmole and Tovar (1968) observed that Royal Terns may feed their young throughout their first winter and into early spring due to the juveniles inability to forage efficiently. This extended parental care, along with

potential food shortages, increases the likelihood that a change in prey availability might affect the life cycle of the terns. Given their diverse diet of forage fishes high in the food chain, Royal Tern diet can be used to assess fish stock abundance and act as a potential bioindicator on the health of the local marine/estuarine ecosystem.

The purpose of this study was to investigate the diet composition of Royal Tern chicks on Fisherman Island National Wildlife Refuge, Virginia, through two breeding seasons. Specifically, I quantified the diet of Royal Terns to determine seasonal and annual percent of prey consumed and compared existing fishery data on stock abundance in the Chesapeake Bay. Here, I test the hypotheses that if Royal Tern chick diet is reflective of prey availability in the Bay, and Royal Tern parents select prey items that are high in abundance for their chicks, then fisheries data can serve as an index of the health of the marine environment. Tern diets would reflect foraging conditions, provisioning decisions, and energy budgets—all factors that depend on marine food availability and health of the environment before and during the breeding season. Diet composition of Royal Tern chicks in the Chesapeake Bay region will provide a better understanding of the ecological interactions in the boundary waters between coastal estuarine and marine systems.

METHODS

Study Area

This study was conducted at a colony of Royal Terns on Fisherman Island National Wildlife Refuge (FINWR, 37° 8'N, 75° 57'W) from early June to late July 2003 and 2004 (Fig.1). The barrier islands of Virginia provide a unique opportunity to study Royal Terns as an indicator species. The islands support the most northern breeding populations on the Atlantic seaboard, and FINWR hosts one of the largest colonies. Fisherman Island is located at the



FIGURE 1. Location of Fisherman Island National Wildlife Refuge in the Chesapeake Bay, Virginia, where Royal Terns breed.

southern tip of the Delmarva Peninsula, at the mouth of the Chesapeake Bay. This distinctive location offers critical habitat and access to abundant prey for terns during their breeding cycle. In 2003, the colony consisted of ~1150 nests, and with a comparable number (~1120) in 2004. Scant vegetation was present within the colony, and the terns primarily used a large contiguous area of bare sand for nesting during both years. The population remained relatively stable despite disturbance from nearby nesting Herring Gulls (*Larus argentatus*), plant succession in nesting habitat, and mammalian and avian predation. A small (<8 nests) population of Sandwich Terns (*Sterna sandvicensis*) nested within the Royal Tern colony in both years.

Diet Observations

Royal Tern diet was quantified with systematic stationary observations of adults feeding chicks at the colony throughout the breeding season. Chicks were observed for a continuous seven-week period. Observations were conducted from 06:30 to 21:00 using 8 x 42 binoculars from the perimeter of the colony or crèche. Weather depending, the chicks were monitored during 30-minute periods 3-4 times per day for 3-5 days per week during different tidal stages from early June, when most chicks begin hatching, until late July, when most chicks fledged (28 - 30 days old). Given the nature of the colony, observation locations changed due to the formation and movement of the crèche. Terns carry single prey items in their bills to their chicks and the prey may be identified by visible external characters, morphology, and markings. Prey size also was estimated relative to adult bill length (BL) and divided into five categories: $< \frac{1}{2}$, $\frac{1}{2}$ - 1, 1 - $1 \frac{1}{2}$, $1 \frac{1}{2}$ - 2, > 2 BL. Most prey items were identified to family; otherwise, they were categorized as unidentified finfish or unknown. Seasonal observations were divided into four bi-weekly periods that corresponded to the spring tides that occurred during the full and new moon period.

To evaluate the possible relationship between time of day and the type of prey brought to the chicks, each breeding season was divided into three seasonal periods: early, mid, and late season (2003: 10 – 22 June, 23 – 06 July, 07 June – 23 July; 2004: 07 – 21 June, 22 June – 03 July, 05 – 21 July). This division provided a similar number of days within each seasonal period because the number of observation days differed between 2003 and 2004. During each seasonal period, the time of day was divided into one-hour time blocks beginning at 07:00 and ending at 15:00. For each time block, the number and type of prey per hour brought to the chicks were recorded.

To reduce observer bias in prey identifications, fishes that were regurgitated during the sampling effort were collected, identified, and cataloged as voucher specimens for those taxa identified during observation periods (Appendix A). Additionally, these fishes, along with others obtained from beach seining efforts, were used to test my observation skill. An assistant held a fish at varying distances from me while I tried to correctly identify the type and length of prey (Appendix B). This method allowed the observer to gain confident identification skills. Both of these methods proved useful and beneficial to the study.

Fish Samples

Forage fish stock abundance and distribution data were obtained from the Virginia Institute of Marine Sciences (VIMS), Gloucester Point, Virginia, and the Chesapeake Bay Fishery - Independent Multispecies Survey (CHESFIMS), Solomons, Maryland. Young of the year and yearling fishes were the targets of the study and the common goal was to measure the spatial distribution, abundances, and biological interactions of these fishes. Inshore fish-sampling results were conducted by VIMS during their bi-monthly summer haul seines in 2003 and 2004 on three beach sites in the lower Chesapeake Bay: FINWR, Kiptopeke State Park, and Silver Beach

YMCA Camp. Sampling periods for the summers included dates from 11 June – 20 August 2003 and 14 June – 26 August 2004. CHESFIMS studies consisted of mid-water trawls along the lower Eastern Shore regions of Virginia. In 2003, due to inclement weather, only three stations in lower portion of the Bay were sampled during a one-day period (8 July) while in 2004 a more complete sampling of seven stations occurred on 7 - 8 July. Data collected by VIMS and CHESFIMS included, but were not limited to, the total number of fish, species composition, and size range per sampling effort. Trawling and seining data points from the mid-bay (37° 9 N) south to the mouth of the Chesapeake (referred to as “lower bay”) were chosen due to their proximity to Fisherman Island (Fig. 2) and the foraging range of Royal Terns from their colony as estimated from previous studies (Erwin 1977). These data should be useful to assess the availability of prey to plunge-diving surface feeding birds, like Royal Terns, and the beach seines provided additional support to the types of prey also available to the terns.

Statistical Analysis

When assumptions of normality of residuals and homogeneous variance were not met, data were analyzed with Kruskal-Wallis (when $df \geq 2$) tests. If variances were unequal after transformation, then Kruskal-Wallis tests were used on non-transformed data. All critical values for the non-parametric tests are reported as Chi-square values. Nonparametric correlation (using Spearman's correlation coefficient) analyses were conducted to detect correlations between diet and season. Pearson Chi - square tests were conducted to compare size categories and types of prey items across time periods. All statistical tests were completed with the SAS software program (Version 8.1, 1999-2000, SAS Institute, Inc.).

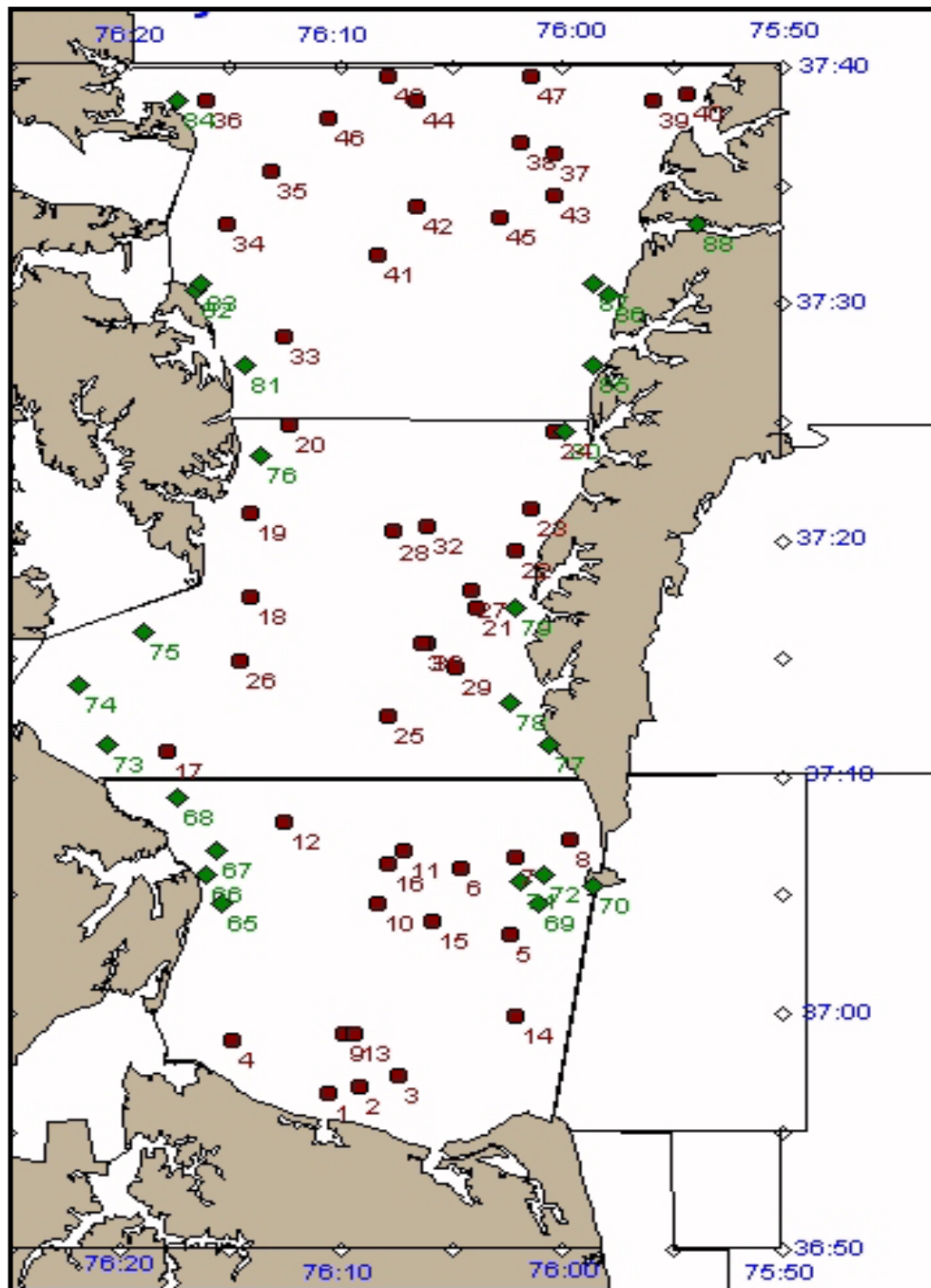


FIGURE 2. Location of CHESFIMS trawl points in the lower Chesapeake Bay from 37:10 to 36:50 South. Fisherman Island National Wildlife Refuge is located at point 70.

RESULTS

Diet Composition

A total of 11,566 and 33,646 prey items was identified during 44 and 87.5 hours of observations during 2003 and 2004, respectively (Table 1). In 2003, fewer prey items were observed than in 2004. The percentage of unidentified finfish to total prey observed was 8.59% in 2003 and 1.79% in 2004. The majority of identified prey items were anchovy, herring, and silversides for both years. A third fewer prey were observed in 2003 than in 2004 due to poor weather with fewer hours of observation.

Adult bill length (BL) data were obtained from a previous study, in which the average length was $63.9 \text{ mm} \pm 2.4 \text{ SD}$ (Wambach and Emslie 2003). The overall percent of each food size category fed to chicks in 2003 and 2004, respectively, are: $<1/2 \text{ BL} = 2.9 \%, 0.83 \%$; $1/2 - 1 \text{ BL} = 12.61 \%, 11.69 \%$; $1 - 1\frac{1}{2} \text{ BL} = 80.57 \%, 87.07 \%$; $1\frac{1}{2} - 2 \text{ BL} = 3.79 \%, 1.20 \%$ and $>2 \text{ BL} = 0.13 \%, 0 \%$ (Fig. 4). Fishes of size $1/2 - 1$ and $1 - 1\frac{1}{2} \text{ BL}$ comprised the bulk of the food being fed to the chicks, particularly those fish whose lengths corresponded to modal size $1 - 1\frac{1}{2} \text{ BL}$.

In both years, prey type that comprised more than 2% of the total prey observed during at least one time period of the diet study was considered a major prey item for that year (Table 1). Prey fluctuated seasonally in type (Fig. 3) and size (Fig. 4). For example, the percentage of anchovy in a chick's diet decreased over time, while the percentage of herring increased (Fig. 3). Wambach and Emslie (2003) found that the proportions of major prey items in the diets of Royal Terns did not vary among ebb, flood, high and low tidal stages, indicating that tidal cycles did not affect the proportion of prey in the diet. This could not be tested in my study during either year because of the inability to survey the colony efficiently during high tides resulting in observations not being evenly represented among the four tidal stages (ebb, low, flood, and

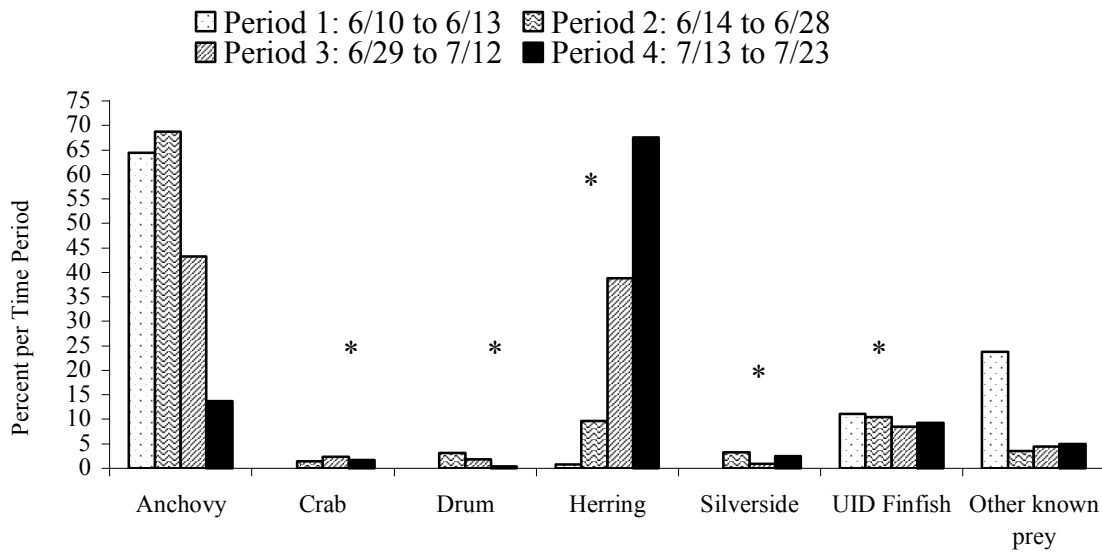
Table 1. Taxa of Royal Tern prey observed at Fisherman Island National Wildlife Refuge, Virginia. A total of 11,577 and 33,646 prey items was observed during 44 hr in 2003 and 87.5 hr in 2004. Numbers in parentheses are percent of total prey.

Prey	2003		2004	
Engraulidae (anchovies)				
<i>Anchoa hepsetus</i> , <i>A. mitchilli</i>	4757	(41.09)	5652	(16.80)
Clupeidae (herrings)				
<i>Brevoortia tyrannus</i> , <i>Opisthonema oglinum</i>				
<i>Alosa</i> spp.	4563	(39.41)	23,086	(68.61)
Atherinidae (silversides)				
<i>Menidia menidia</i>	243	(2.09)	2462	(7.32)
Brachyura (crabs)	208	(1.79)	587	(1.74)
Sciaenidae (drums)				
<i>Micropogonias undulates</i> , <i>Leiostomus xanthurus</i> , <i>Cynoscion</i> spp.	195	(1.68)	430	(1.27)
Pleuronectiformes (unidentified)	111	(0.96)	155	(0.46)
Sparidae (porgies)				
<i>Lagodon rhomboides</i> , <i>Archosargus probatocephalus</i>	102	(0.88)	1	(0.002)
Cyprinodontidae (killifish)				
<i>Fundulus majalis</i>	97	(0.84)	-	
Syngnathidae (seahorses, pipefish)				
<i>Hippocampus</i> spp., <i>Syngnathus</i> spp.	76	(0.65)	75	(0.22)
Merluccidae (hakes)				
<i>Urophycis chuss</i>	54	(0.46)	234	(0.70)
Anguillidae (freshwater eels)				
<i>Anguilla rostrata</i>	38	(0.33)	51	(0.15)
Carangidae (jacks)				
<i>Caranx</i> spp.	18	(0.15)	-	
Belonidae (needlefish)				
<i>Strongylura marina</i>	11	(0.09)	8	(0.02)
Triglidae (searobins)				
<i>Prionotus</i> spp.	9	(0.07)	27	(0.08)
Cynoglossidae (tonguefish)				
<i>Symphurus</i> spp.	6	(0.05)	33	(0.09)
Ophichthidae (eels)	-		155	(0.46)
Serranidae (sea basses)				
<i>Centropristis striata</i>	-		62	(0.18)
Penaeidae (shrimps)				
<i>Penaeus</i> spp.	3	(0.02)	4	(0.01)
Loliginidae (squids)	-		4	(0.01)

Table 1 continued.

Prey	2003		2004	
Odonata (dragonflies)	1	(0.64)	-	
Unidentified finfish	995	(8.59)	605	(1.79)
Unknown	90	(0.77)	15	(0.04)

A.



B.

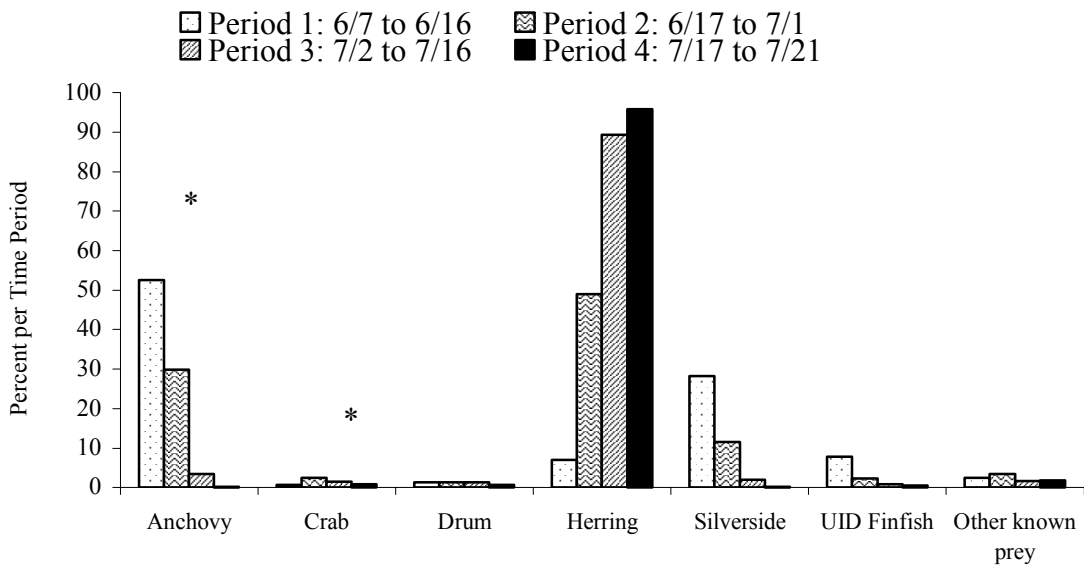
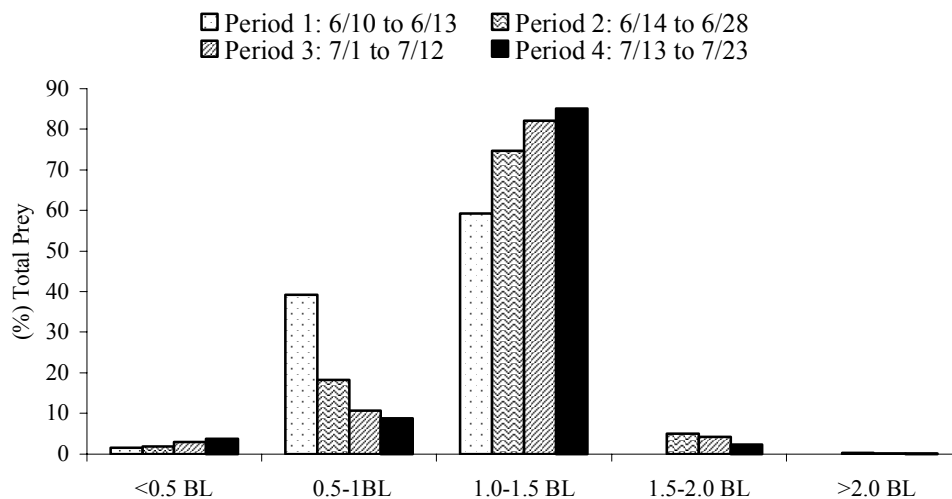


FIGURE 3. Percent of major prey identified during 30-min observations in (A) 2003 and (B) 2004. Asterisks indicate significant seasonal variation ($P < 0.05$) for prey items comprising at least 2% of total prey observed during any period. UID is unidentified.

A.



B.

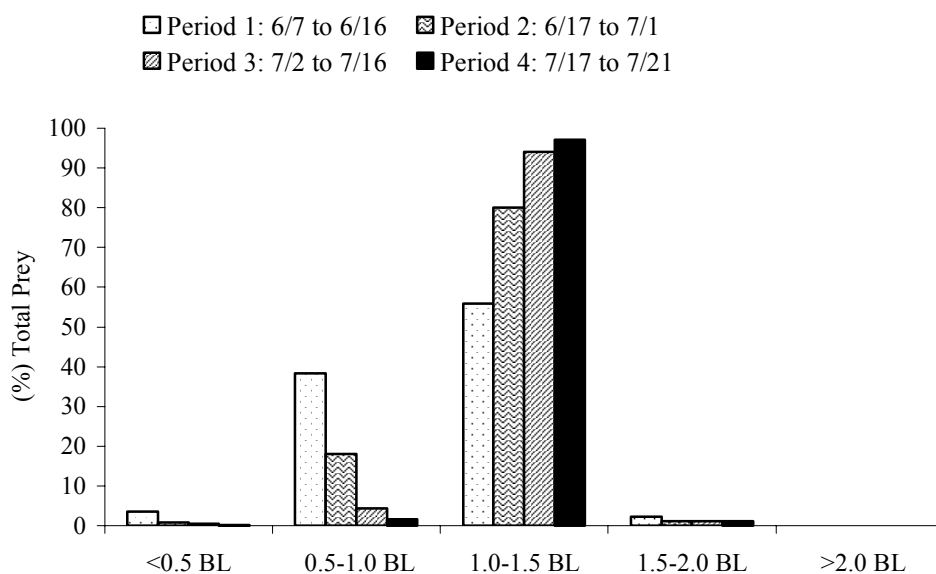


FIGURE 4. Percent prey brought to chicks by size categories estimated relative to bill length. Prey size increased significantly among time periods throughout the breeding season; (A) 2003: Pearson $\chi^2 = 325.81$, $df = 12$, $P < 0.001$ and (B) 2004: $\chi^2 = 3375.15$, $df = 12$, $P < 0.001$.

high). However, the size of the prey being fed to the chicks varied significantly within each of the lunar bi-weekly time periods for each year (Table 2).

In 2004, the proportion of anchovies to total prey brought to chicks decreased across time periods (2003: $\chi^2_3 = 4.11$, $P = 0.25$; 2004: $\chi^2_3 = 7.98$, $P < 0.05$; Fig. 3), and was inversely correlated to date (2003, $r_{140} = -0.01$, $P = 0.86$; 2004, $r_{150} = -0.02$, $P < 0.01$). Herring increased significantly by time period in 2003 ($\chi^2_3 = 19.73$, $P < 0.001$) and in 2004 there was no significant difference ($\chi^2_3 = 2.51$, $P = 0.47$). Herring were observed more per period towards the end of the season in 2003 ($r_{140} = 0.31$, $P < 0.01$). However, in 2004 there was no correlation between herring observed and date ($r_{150} = 0.07$, $P = 0.40$), although terns were observed feeding herring more to their chicks earlier and throughout the 2004 season. The proportion of silversides identified per trial was positively correlated with date in 2003 ($r_{140} = 0.16$, $P < 0.05$) and varied significantly among time periods ($\chi^2_3 = 10.19$, $P < 0.02$). However, in 2004 they were not correlated with date ($r_{150} = -0.1538$, $P = 0.06$) and did not vary across time periods ($\chi^2_3 = 4.84$, $P = 0.18$). The proportion of drum observed decreased by time periods in 2003 ($\chi^2_3 = 10.5636$, $P < 0.02$) and did not vary in 2004 ($\chi^2_3 = 7.25$, $P = 0.06$); it was positively correlated by date in 2004 ($r_{150} = 0.17$, $P < 0.05$). The proportion of crab varied significantly across time periods during both years (2003: $\chi^2_3 = 10.69$, $P < 0.02$; 2004: $\chi^2_3 = 9.0432$, $P < 0.05$) and was positively correlated to date in both 2003 ($r_{140} = 0.30318$, $P < 0.01$) and 2004 ($r_{150} = 0.21$, $P < 0.01$). The proportion of unknown finfish to total prey brought to chicks varied significantly by time periods in 2003 ($\chi^2_3 = 9.40$, $P < 0.05$) and was positively correlated by date ($r_{140} = 0.27$, $P < 0.01$). However, in 2004, the proportion did not vary by time period ($\chi^2_3 = 6.01$, $P = 0.11$) and was negatively correlated by date ($r_{150} = -0.21$, $P < 0.02$). Prey items that were not considered major prey, which were analyzed collectively, did not vary by time period ($\chi^2_3 = 6.01$, $P = 0.11$) and

Table 2. Results of Kruskal-Wallis tests on five prey size categories observed being fed to chicks during biweekly lunar time periods.

2003			2004		
Time Period	X^2_4	P	Time Period	X^2_4	P
10 June – 13 June	30.1485	< 0.001	07 June – 16 June	69.1990	< 0.001
14 June – 28 June	152.8802	< 0.001	17 June – 01 July	199.3864	< 0.001
01 July – 09 July	103.4100	< 0.001	02 July – 16 July	133.1248	< 0.001
13 July – 23 July	88.1788	< 0.001	17 July – 21 July	37.8650	< 0.001

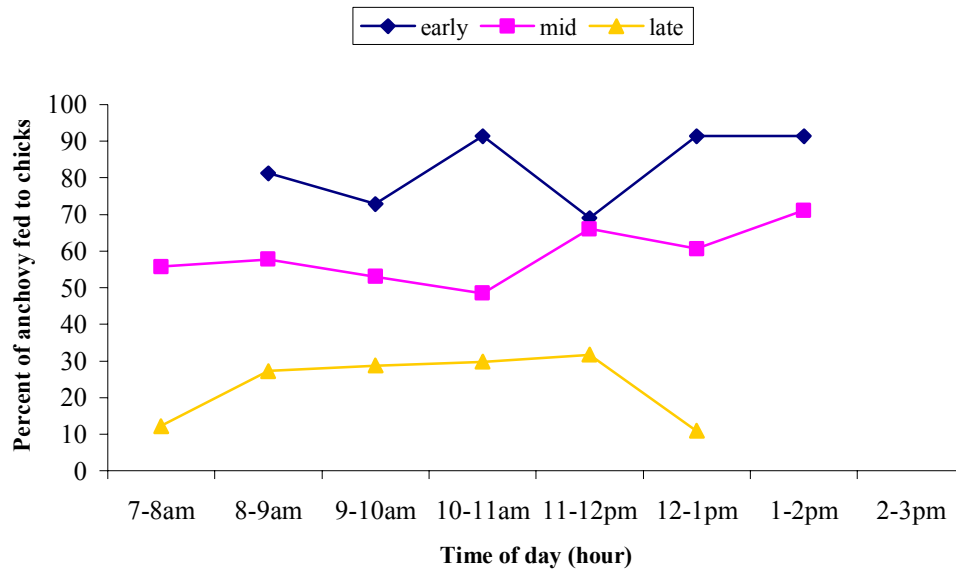
was negatively correlated by date ($r_{150} = -0.21$, $P < 0.02$). Prey items that were not considered major prey, which were analyzed collectively, did not vary among time periods (2003, $\chi^2_3 = 0.63$, $P = 0.89$; 2004, $\chi^2_3 = 7.06$, $P = 0.07$) and were not correlated to date (2003, $r_{140} = 0.19$, $P = 0.13$; 2004, $r_{150} = 0.09$, $P = 0.28$) in either years.

With respect to time of day, in 2003 the percentage of anchovy and herring fed to chicks remained constant throughout the day for the early, mid, and late seasonal periods. A shift in prey occurred during the late period when herring dominated the diet instead of anchovy (Fig. 5). Similar results were observed in 2004, however the shift occurred during the mid - season period (Fig. 6). The size of prey increased seasonally during both years (Fig. 4; 2003, $\chi^2_{12} = 325.81$, $df = 12$, $P < 0.001$; 2004, $\chi^2_{12} = 302.87$, $df = 12$, $P < 0.01$). Intermediate fish sizes ($\frac{1}{2}$ - $1\frac{1}{2}$ BL) appeared to be abundant dietary items during 2003 (92 -98%) and 2004 (94 -98%). This difference may be a reflection of seasonal variation where prey length increases seasonally in relation to chick growth and availability of prey items, as suggested by Wambach and Emslie (2003), instead of a taste preference by the foraging adult or a chick's ability to swallow larger fish as the season progressed.

Fisheries Data

VIMS seining efforts during 2003 and 2004 show that the number of anchovies fluctuated during the season, but they were the highest caught fish during the seining effort on 24 July 2003 (Fig. 7; 58% of total prey). In 2004, they were the second most abundant fish, but caught in lower numbers. Except for 24 July 2003, silversides were caught consistently and were the most abundant fish seined for all dates (2003, 35- 98%; 2004, 53- 97%). Perch was the most prevalent fish seined on 5 August 2003 (58%). These results are not consistent with the diet observations

A.



B.

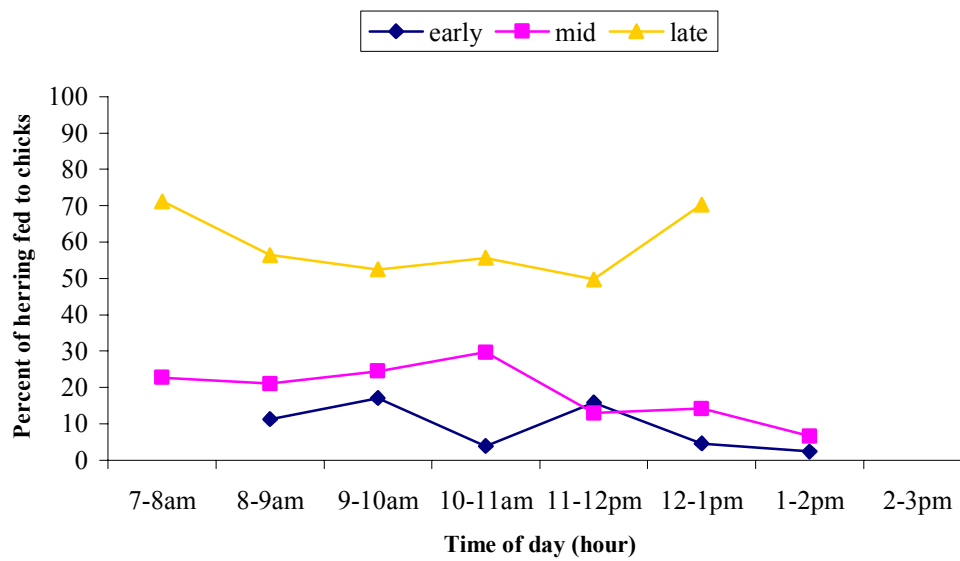
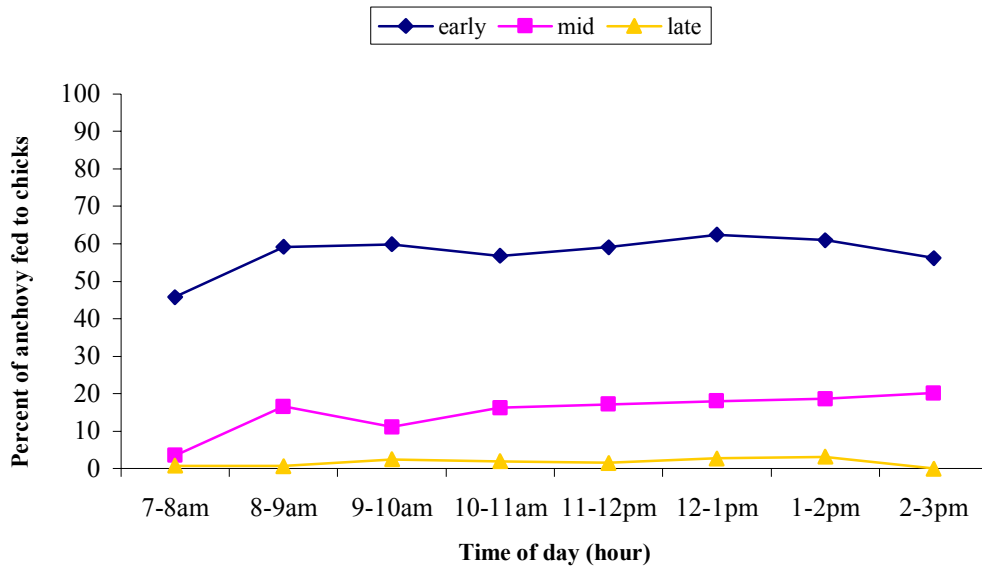


FIGURE 5. Percent of (A) anchovy and (B) herring fed to Royal Tern chicks in 2003 during different times of day in the early, mid, and late parts of the breeding season.

A.



B.

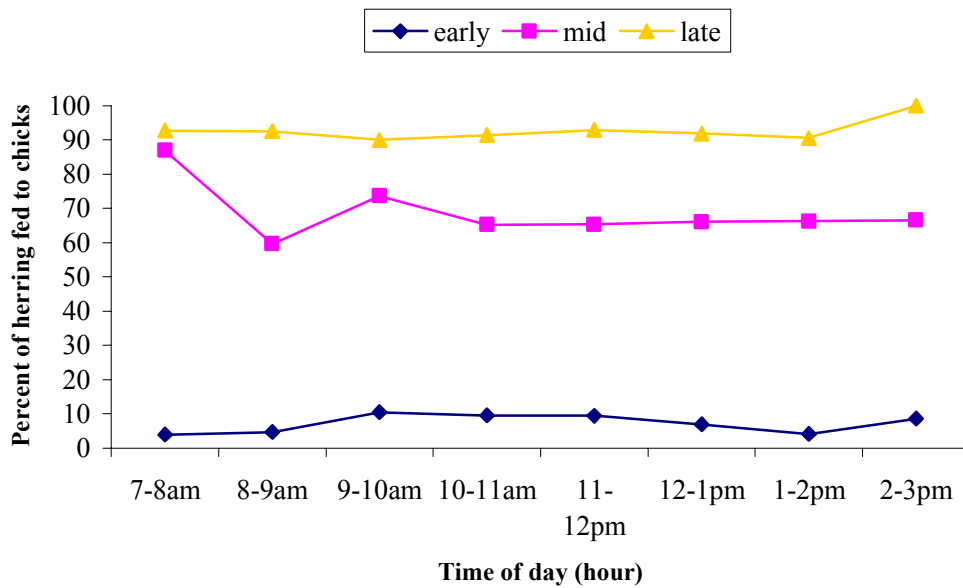
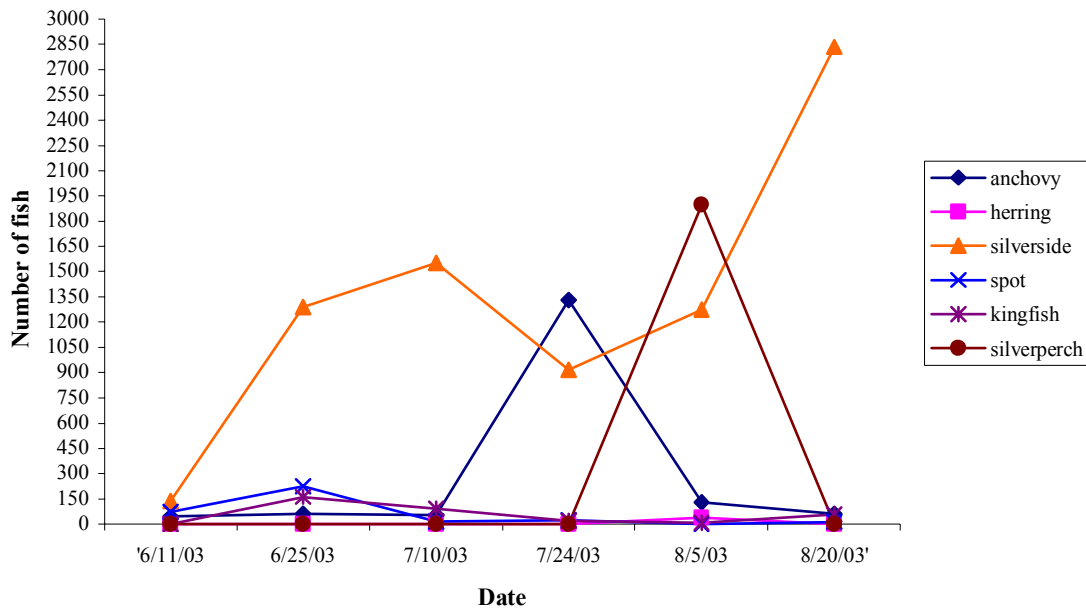


FIGURE 6. Percent of (A) anchovy and (B) herring fed to Royal Tern chicks in 2004 during different times of day in the early, mid, and late parts of the breeding season.

A.



B.

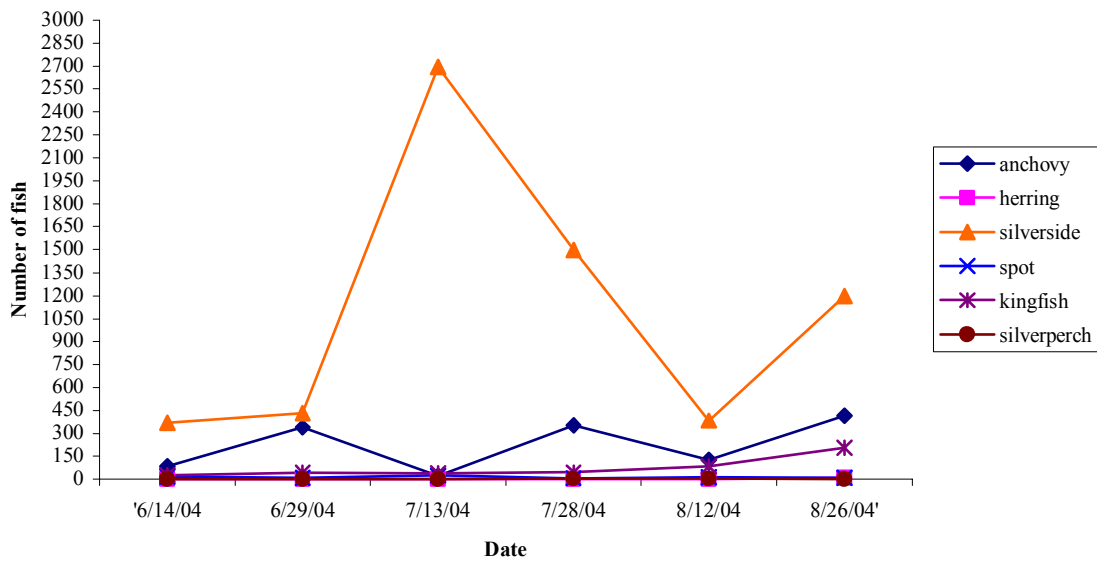


FIGURE 7. Virginia Institute of Marine Sciences (VIMS) combined beach seines of fish at three locations in the lower Chesapeake Bay during (A) 2003 and (B) 2004.

obtained at the colony, perhaps indicating that Royal Terns forage at a greater distance from the shore.

Trawl surveys conducted by CHESFIMS indicate that anchovies are the most prevalent species caught during the surveys (Table 3). Other species caught, in lower numbers, include herring, drum and butterfish. These results are not consistent with the VIMS seines along the eastern shore during the same time periods, however they are comparable to diet observations. These data indicate that these forage fishes are patchy in abundance and distribution and terns are specialized in locating these fishes.

The length of Bay Anchovies was measured during trawl surveys conducted by VIMS during 2003. The dates of the surveys are as follows for the lower Chesapeake Bay stations: 9, 10, 16, 19 June and 2, 3, 7, and 10 July. A total of 1520 anchovies was measured and 76.5% of anchovies sampled were in the size class 64-97.7 mm, which corresponds to tern bill length $1 - 1\frac{1}{2}$ (Fig. 8). This is consistent with my findings that this size class of fishes are predominant in the diets of Royal Terns. Thus, indicating that the terns are exploiting a resource that is dominated by this size class of fish and are not selecting one size class over another.

DISCUSSION

Seasonality and the Variation in Prey Type and Size

Seasonal variation in prey type and size in the diet of Royal Terns has been examined in only a handful of studies along the Atlantic coast of the United States. Killifish (*Fundulus*), anchovy (*Engraulida*), and menhaden (*Brevoortia*) were found to be major food items in the diet of Royal Terns in North Carolina and Virginia (Buckley and Buckley 1972). Additionally, in Virginia, Erwin (1977) found other common prey items such as silversides (*Menidia*), Spot (*Leiostomus xanthurus*), Striped Mullet (*Mugil cephalus*), and Butterfish (*Peprilus triacanthus*),

Table 3. Total number of species caught during the Chesapeake Bay Fisheries-Independent Multispecies Survey (CHESFIMS) trawl of the lower Chesapeake Bay. A total of seven different stations were sampled in 2003 and 2004. In 2003, three stations were sampled and in 2004 the same stations were sampled along with four additional stations.

	7 July 03	7 July 04	8 July 04
Engraulidae (anchovies)			
<i>Anchoa hepsetus</i> , <i>A. mitchilli</i>	292	1877	322
Clupeidae (herrings)			
<i>Opisthonema oglinum</i> , <i>Brevoortia tyrannus</i>	1	36	0
Sciaenidae (drums)			
<i>Cynoscion regalis</i> , <i>Micropogonias undulates</i> , <i>Leiostomus xanthurus</i> , <i>Menticirrhus saxatillis</i>	1	52	19
Pleuronectiformes (flatfishes)			
<i>Scophthalmus aquosus</i> , <i>Citharichthys</i> <i>spilopterus</i> , <i>Paralichthys dentatus</i> , <i>Etropus microstomus</i> , Bothidae spp.	1	7	1
Triglidae (searobins)			
<i>Prionotus</i> spp.	2	8	0
Merluccidae (hakes)			
<i>Urophycis regia</i>	0	1	0
Stromateidae (butterfish)			
<i>Peprilus triacanthus</i>	0	20	3
Brachyura (crabs)			
<i>Rithropanopeus harrisii</i> , <i>Ovalipes ocellatus</i> , <i>Callinectes sapidu</i>	0	10	2
Ophichthidae (eels)			
<i>Ophidion marginatum</i>	0	1	0
Syngnathidae (pipefish)			
<i>Syngnathus fuscus</i>	0	1	0
Sparidae (porgies)			
<i>Stenotomus chrysops</i>	0	4	1
Rajidae (skate and rays)			
<i>Rhinoptera bonasus</i>	0	1	0
<i>Raja eglanteria</i>	0	1	0

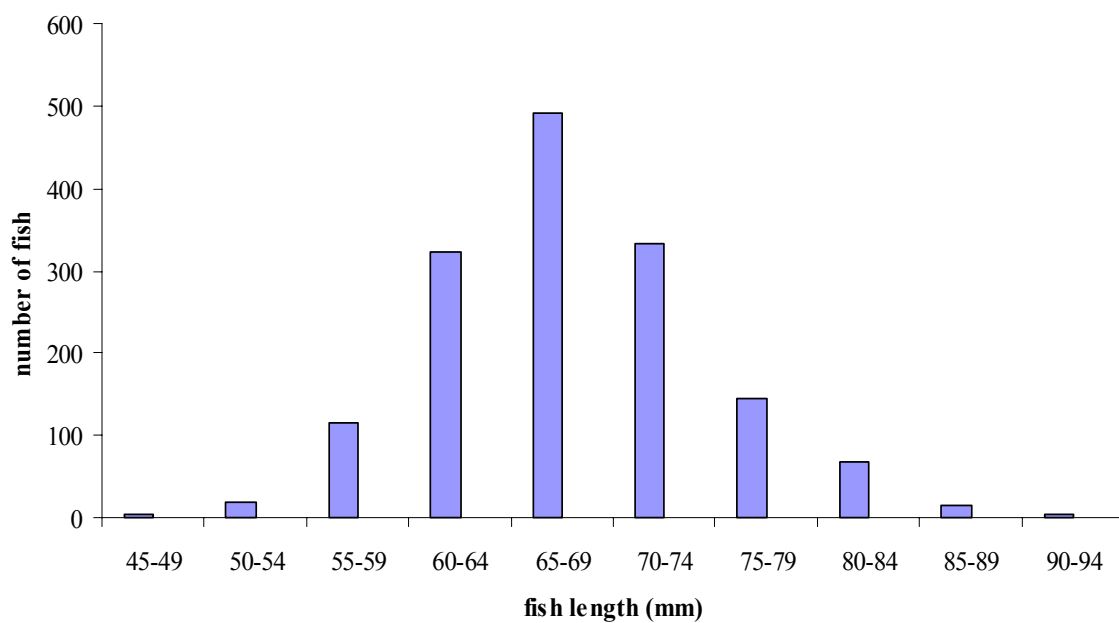


FIGURE 8. Bay Anchovy length data from trawls in the lower Chesapeake Bay, 2003.
Source: Virginia Institute of Marine Sciences.

while Ihle (1984) found that fish (86%) and soft-shelled Blue Crabs (*Callinectes sapidus*; 14%) comprised the bulk of the diet of Royal Terns. Recent work conducted by McGinnis and Emslie (2001) and Wambach and Emslie (2003) found that Royal Tern parents in North Carolina fed their chicks a variety of prey items such as anchovies, herring, jacks, mackerels, drums, porgies, and mullets. These results are consistent with results presented here. Elsewhere, similar results are observed with another species, the Crested Tern (*Sterna bergii*). Their chicks on Phillip Island, Australia, experienced significant seasonal and annual differences in the diet, and Australian Anchovy (*Engraulis australis*) comprised 63% of the prey (Chiaradia et al. 2002).

The ranking of prey items seasonally may reflect differences in the availability of suitable prey. Wambach and Emslie (2003) found four taxa of fish species important to terns during the chick-rearing period in North Carolina varied in frequency during two years of study. In 1999, anchovies (12.6%), herring (11.5%), drum (12.8%) and mullet (7.0%) were the major prey items. The following year, anchovies (11.9%), herring (20.3%), drum (24.7%) were the three most abundant fishes; however, tonguefish (*Cynoglossidae*, 4.1%) and shrimp (*Penaeidae*, 6.2%) also appeared in the diet.

Size of prey varied throughout the season, as has been demonstrated in Royal Terns (McGinnis and Emslie 2001, Wambach and Emslie 2003), Common Terns (*Sterna hirundo*; Burness et al. 1994, Brenninkmeijer et al. 2002) and Black Skimmers (*Rynchops niger*) in the Chesapeake Bay (Held 2003). Smaller fish were important early in the season, and as the season progressed, larger prey items became more predominant.

Results here indicate that Royal Terns may exhibit some prey selectivity while foraging for a growing chick and that there are at least three genera of fish important during the breeding season. Also, significant changes in the sizes of prey in the diet may be an indication of this

variation. Based on VIMS trawl data from 2003, the average length of a bay anchovy was 68.04 mm. Additionally, the mean prey size of $\frac{1}{2} - 1 \frac{1}{2}$ BL may reflect the availability of prey within this size class and not the preference of the terns to select for this size, thus the terns may be foraging opportunistically.

Diet Composition and Fisheries Data as Indicators of Prey Availability

Seasonal variation in diet during the breeding season has also been documented in other tern species (Safina and Burger 1989, Safina et al. 1990, Shealer 1998, Amey and Diamond 1997). Since the time of day did not affect the terns ability to capture a consistent proportion of anchovies within each portion of the season, the decline of anchovies in the diet and shift to herring during mid to late season in my study, suggest that anchovy availability decreased in the tern's foraging area near Fisherman Island. This indicates that abundance, not parental selection, is the limiting factor in the diet of Royal Terns.

In the Chesapeake Bay, Bay Anchovies occur throughout the region and spawn from late April through late September with the peak occurring in early July. Adults live up to three years and rarely grow beyond 90 mm, but males can be as long as 100 mm (VIMS 2005). Seining and trawling surveys have indicated that these fishes fluctuate annually and are patchy in distribution. It appears that Royal Terns are feeding on older age classes of adult anchovy who may be the breeders of the year. The reduction of anchovies later in the chick-feeding season indicates that once the anchovies spawn, their availability decreased and thus terns shift prey to a more abundant species.

Coincidentally, the timing of the prey switch corresponds with the herring migration out to sea. Herring are also a highly schooling species that are found near the surface, with younger schools found in locations more south along the coast (Chesapeake Bay Ecological Foundation,

Inc. 2005). Thus, they can be easily exploited. Given the dynamic nature of these forage fish, a change in their availability may result in a change in the diet of Royal Terns. This has been documented in other regions of the Atlantic with generalist-feeding seabirds (Montevecchi et al. 1987; Furness and Nettleship 1991).

The increase of herring species during each period of both years, peaking near the end of the breeding season, indicates that Royal Terns were perhaps exploiting a resource that was in high abundance. The consistent high percentage at which herring were fed throughout the day support this idea. Menhaden, unlike anchovies, are of commercial importance and are one of the most abundant fishes in the Chesapeake Bay. Their spawning areas include the offshore regions of Virginia where the larvae then spend their first year in protected estuaries of the Bay. During the spring, these juvenile menhaden form large schools with adult menhaden and begin migrating out to sea. One-year old menhaden typically found in the Bay average 127 mm in length (VIMS 2005). Commercial fisheries data suggest that menhaden are declining in number, and in 2000 landings were the second lowest since 1940 (Chesapeake Bay Ecological Foundation, Inc. 2005). Further examination of the relationship between local fisheries distributions and Royal Tern productivity is warranted due to the possibility that menhaden declines might cause Royal Tern declines in the future.

This seasonal and annual shift in the diet has been documented for another top-level piscivorous estuarine predator in the Chesapeake Bay, the Striped Bass (*Morone saxatilis*). During the summer and fall, Atlantic Menhaden and Bay Anchovy were the dominant prey and juvenile Spot (*Leiostomus xanthurus*) and Atlantic Croaker (*Micropogonias undulates*) were the dominant prey in winter (Hollis 1952). However in later studies, Atlantic Menhaden, Bay Anchovy and Spot were the primary prey items throughout the year (Hartman and Brandt

1995a). These apparent shifts in food habits of striped bass may represent changes in prey abundance.

Common Terns in southern Brazil show seasonal variation in their winter diet and there is evidence of temporal variation in the prey size and prey species selected (Bugoni and Vooren 2004). Given the life histories of these forage fishes, it can be concluded that Royal Terns feed their chicks a diet consisting mostly of adult anchovies and silversides which are spawning in near by waters and age one herring that are migrating for the first time to sea. These fishes occur in high abundance and are easily obtained by the terns, thus terns switch prey due to the availability of various forage fish species of different sizes.

The beach seine and trawl fisheries data collected from VIMS and CHESFIMS, while informative, do not provide a reliable means for assessing the true spatial and temporal distribution of forage fishes in the lower Chesapeake Bay as it pertains to this study. Sampling methods, weather problems and sparse data collection contributed to the lack of quality valid comparisons between forage fishes and the diet of Royal Tern chicks. Thus, records are not consistent between years due to the differences between sampling sites and could not be compared. Seining on Fisherman Island was at a location that was in close proximity to marsh tidal creeks that potentially serve as staging areas for fishes, like silversides, which are smaller in size and were the most abundant fish during the seines. Erwin (1977) suggested that Royal Terns may not be capturing this abundant prey item due to their inability to properly handle them. For example, smaller terns, like the Common Tern, can easily exploit this plentiful prey type because of the smaller body size of the fish. In deeper regions of the Bay, trawling records indicate that anchovies are plentiful and that their abundance, although patchy. Also, the size of anchovies sampled was consistent with the observed sizes being fed to chicks. Thus, contrasted with the

beach haul seines, the trawling information shows spatial variability between sampling sites and a greater patchiness of fish indicating that perhaps the best assessment of prey availability is with trawl data.

CONCLUSION

In its summer breeding area in the southern Chesapeake Bay, Royal Terns feed their chicks primarily juvenile herring and adult anchovies, but with great temporal variation in the composition of the diet in terms of prey size and species. Prey length increases seasonally with the availability of certain prey types, like herring. The birds switch from one prey species to another, according to the availability of food patches based on the spawning and migratory patterns of the forage fishes. This temporal variation in the diet is due to the availability of prey species and reflects the patchy dynamics of prey populations, as indicated by fisheries data.

Fisheries data, along with the diet information, could serve as an indicator for relative abundance of fish stocks of preferred prey, if collected in the correct form, as it has been demonstrated for the Arctic Tern (Monaghan et al. 1989a, 1989b, Amey and Diamond 1997), Elegant Tern (*Sterna elegans*; Velarde et al. 1994), Pigeon Guillemot (*Cephus columba*; Litzow et al. 2000), and Common Murre (*Uria aalge*; Davoren and Montevecchi 2003). These types of data are needed over several breeding seasons to further characterize the feeding ecology of Royal Terns in the southern Chesapeake Bay as well as the dynamic forage fish stocks that are valuable to seabirds and other top-level predators such as Striped Bass.

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APPENDIX

Appendix A. Number and taxa of prey regurgitated during chick banding of Royal Terns and Sandwich Terns nesting on Fisherman Island National Wildlife Refuge, VA, 2003 and 2004.

Family	Species	Common name	Number by Date	
			7/07/03	7/07/04
Clupidae	<i>Opisthonema oglinum</i>	Atlantic Thread Herring	4	5
	<i>Brevoortia tyrannus</i>	Atlantic Menhaden	1	6
	<i>Alosa aestivalis</i>	Blueback Herring	2	3
	Unidentified	Herring	3	6
	Total		10	20
Engraulidae	<i>Anchoa mitchilli</i>	Bay Anchovy	25	10
Triglidae	Unidentified	Searobin	-	8
Sparidae	<i>Lagodon rhomboids</i>	Pinfish	1	-
Serranidae	<i>Centropomus striatus</i>	Black Sea Bass	-	7
Atherinidae	<i>Menidia menidia</i>	Atlantic Silverside	-	6
Brachyura	unidentified	Crab	5	3
Loliginidae	unidentified	Squid	-	2
Penaeidae	unidentified	Shrimp	-	1
Syngnathidae	<i>Hippocampus</i> spp.	Seahorse	1	-
	<i>Syngnathus</i> spp.	Pipefish	2	1
Pleuronectiformes	<i>Trinectes maculatus</i>	Hogchoker	1	2
Cynoglossidae	<i>Symphurus</i> spp.	Tonguefish	-	1
Unknown			3	7

Appendix B. Validation tests of prey type and length in 2003. Prey collected from beach seines and regurgitations of Royal Tern chicks on Fisherman Island National Wildlife Refuge, VA.

Fish species	Identified as	Correct?	Length	Identified as	Correct?
Spot	drum	yes	76 mm	1 – 1 ½	yes
Bay Anchovy	anchovy	yes	70 mm	1 – 1 ½	yes
Black Sea bass	bass	yes	65 mm	1 – 1 ½	yes
Atlantic Needlefish	needlefish	yes	120 mm	1 ½ - 2	yes
Black-cheek Tonguefish	flatfish	yes	61 mm	½ - 1	yes
Atlantic Silverside	anchovy	no	67 mm	1 – 1 ½	yes
Bay Anchovy	anchovy	yes	68 mm	1 – 1 ½	yes
Atlantic Croaker	drum	yes	85 mm	1 – 1 ½	yes
Atlantic Menhaden	herring	yes	119 mm	1 – 1 ½	yes
Atlantic Thread Herring	herring	yes	74 mm	1 – 1 ½	yes
Northern Pipefish	pipefish	yes	101 mm	1 – 1 ½	yes
Atlantic Silverside	silverside	yes	66 mm	1 – 1 ½	no
Blue Crab	crab	yes	59 mm	½ - 1	yes
Bay Anchovy	anchovy	yes	87 mm	1 – 1 ½	yes
Spot	drum	yes	84 mm	1 – 1 ½	yes
Northern Kingfish	drum	yes	62 mm	1 – 1 ½	no
Atlantic Silverside	drum	yes	71 mm	1 – 1 ½	yes

